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Growth analysis on a peatland restoration species, Tamanu, under different groundwater levels Ⅰ

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Growth analysis on a peatland restoration species, Tamanu, under different groundwater levels Ⅰ

CONTENTS

This publication contains a part of the results of an international joint research project being conducted by the National Institute of Forest Science (NIFoS) and the University of Sriwijaya in Indonesia from 2024 to 2025,

NIFoS Publication No. 1016, 'Peatland Management Policy in Indonesia'
NIFoS Newsletter 23-06, 'Indonesian Peatland Restoration and Ecosystem Service Value 1'
NIFoS Newsletter 24-01, 'Peatland Research Trends and Climate Change'
NIFoS Newsletter 24-05, 'Indonesian Peatland Restoration and Ecosystem Service Value 2'

This is the fifth publication following the previous ones.

Currently, an international joint research is being promoted to develop a peatland restoration model centered on a 10 ha research site created in Perigi Village, South Sumatra Province, Indonesia. Through this international joint research, the planting of Tamanu (local name: Nyamplung, scientific name: *Calophyllum inphyllum* L.), a peatland restoration tree species and a native species to Indonesia, was completed in 2022. The research goal is to evaluate how much carbon can be stored in the restored peatland through continuous monitoring and accumulation of growth data in the future, and to estimate the long-term carbon reduction potential of the restored peatland.

In the meantime, in 2023, some of the planted Tamanu seedlings died due to extreme wet rainy seasons and long-term flooding. Tamanu seedlings have a very high initial survival rate in peatlands, and the Indonesian Badan Restorasi Gambut dan Mangrove or Peatland and Mangrove Restoration Agency (BRGM) has classified them as a suitable species for peatland restoration. Nevertheless, some of the Tamanu seedlings did not survive due to long-term exposure to high water levels during the extremely long rainy wet season with, heavy rains and long flooding of the peatlands.

To manage unexpected risks and increase the sustainability of the peatland restoration model, the research team studied how the growth of Tamanu seedlings growing in peat soils varies with groundwater levels, and publishes this publication to share the results and introduce current issues.

01

What is Tamanu in peatlands?

Figure 1 Tamanu planted to restore damaged peatlands (NIFoS)

Having the ability to store carbon in the thick peat layer, tropical peatlands play an important role as a global carbon storage. At the same time, forests developed in tropical peatlands provide timber and non-timber forest products, which serve as a source of income for local residents. In addition, tropical peatlands provide various ecosystem services, such as the function of controlling floods or droughts by holding water, and providing habitats for plants and animals.[1)]

1) Leksono, B.; Windyarini, E.; Hasnah, T.M.; Rahman, S.A.; Baral, H. *Calophyllum inophyllum*—A viable prospect for green energyand landscape restoration? In Bioenergy for Landscape Restoration and Livelihoods: Re-Creating Energy-Smart Ecosystems on Degraded Landscapes; Baral, H., Leksono, B., Seol, M., Eds.; Center for International Forestry Research: Bogor, Indonesia, 2022; pp. 178–191.

In particular, tropical peatlands in Indonesia are the second largest in the world.[2] However, due to frequent conversion of peatlands to other types of land for large-scale plantations in Indonesia and artificial drainage during the process of burning vegetation in peatlands for slash-and-burn agriculture, the damage to tropical peatlands is becoming serious.[3] Normally, peat soils store carbon well because they are submerged in water, but when they are surfaced out of the water due to drying or artificial drainage, the organic matter in peat soils decompose quickly and release a large amount of carbon into the atmosphere. It indicates that peatlands that were once carbon storage can change into sources of carbon emissions, causing acceleration of global warming. In addition, dried peatlands become more valuable to fire, and the haze from the fires crosses borders, causing health problems and conflicts between countries.

Peatland restoration cannot be achieved simply by planting trees. If restoration is the only goal without considering the residents who live and depend on peatlands, the local residents who used peatlands as a source of income will inevitably end up damaging the peatlands again. So, the research team tried to find a species that was ecologically suitable for peatland restoration and also valuable as a source of income for local residents, and the research team finally focused on Tamanu, a tropical peatland restoration species in Indonesia.

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2) Gumbricht, T.; Roman-Cuesta, R.M.R.; Verchot, L.; Herold, M.;Wittmann, F.; Householder, E.; Herold, N.; Murdiyarso, D. An Expert System Model for Mapping Tropical Wetlands and Peatlands Reveals South America as the Largest Contributor. Global Change Biology. 2017, 23, 3581–3599.

3) Yuwati, T.W.; Rachmanadi, D.; Pratiwi; Turjaman, M.; Indrajaya, Y.; Nugroho, H.Y.S.H.; Qirom, M.A.; Narendra, B.H.; Winarno, B.; Lestari, S.; et al. Restoration of Degraded Tropical Peatland in Indonesia: A Review. Land, 2021, 10, 1170.

Tamanu's scientific name is *Calophyllum inophyllum* L., and in Indonesian it is called Nyamplung. Its native habitat is Southeast Asia, the southern coast of India, eastern Africa, Australia, and the South Pacific, and it mainly lives in low-elevation riverine and coastal areas. Tamanu seeds have high oil content, so they can be used peatlands to produce high value-added products such as cosmetics and bioenergy.

In other words, Tamanu is an indigenous Indonesian tree species and is recommended by the Indonesian government as a peatland restoration tree species,[4] and it can also contribute to the income of local residents, so it is considered a suitable tree species for sustainable use and restoration of peatlands. In addition, from an ecological perspective, Tamanu is known to adapt well to waterlogging areas and grow well even in degraded land.

After looking into previous studies on Tamanu, some previous studies reported that the survival rate of Tamanu seedlings in Indonesian tropical peatlands was over 80%.[5] However, there has been no research clarified on how Tamanu seedlings adapt to changes in water levels in peatlands.

Indonesian tropical peatlands have very large differences in water levels between the dry and rainy seasons. Can Tamanu seedlings survive in these drastic environmental changes in peatlands? During the dry season, the water level in the peatland drops to a depth of up to −2 m from the ground,

4) Badan Restorasi Gambut (BRG). Rencana Kontijensi Badan Restorasi Gambut: Perubahan (Contingency Planning of Peatland Restoration Agency) ; Badan Restorasi Gambut: Jakarta, Indonesia, 2016. (In Indonesian)

5) Maimunah, S.; Rahman, S.A.; Samsudin, Y.B.; Artati, Y.; Simamora, T.I.; Andini, S.; Lee, S.M.; Baral, H. Assessment of Suitability of Tree Species for Bioenergy Production on Burned and Degraded Peatlands in Central Kalimantan, Indonesia. Land, 2018, 7, 115.

but during the rainy season, it rises to a depth of up to 2 m.[6)] These water level changes greatly influence the survival and growth of planted seedlings. Therefore, an experiment was started to understand the survival and growth characteristics of Tamanu seedlings in peat soils under different groundwater levels.

6) Irfan, M.; Kurniawati, N.; Ariani, M.; Sulaiman, A.; Iskandar, I. Study of Goundwater Level and Its Correlation to Soil Moistureon Peatlands in South Sumatra. Journal of Physics: Conference Series. 2020, 1568, 012028.

02
Research Methods

The Tamanu growth experiment was conducted in the nursery of the University of Sriwijaya. Let's first look at the experimental process to examine the growth characteristics of the seedlings.

To observe the growth characteristics of the Tamanu seedlings, peat soil was collected from the tropical peatland near the University of Sriwijaya in Indonesia. A container was prepared and filled with peat soil to a height of 20 cm. To examine the difference in survival and growth of the seedlings under varying groundwater levels, holes were made in the bottom and sides of the container so that seedlings could be exposed to the groundwater level. Next, seeds were buried in the peat soil, with one-third of the body under the soil and the rest exposed to the air. Finally, pesticides were sprayed to protect the Tamanu seedlings from microorganisms that may be present in the collected peat soil. All 60 seedlings were grown in the same condition for 40 days after sowing without treating the groundwater level.

From 40 days after sowing, five different groundwater level treatments were randomly assigned to each twelve seedlings to examine the effect of the groundwater level (Figure 2).

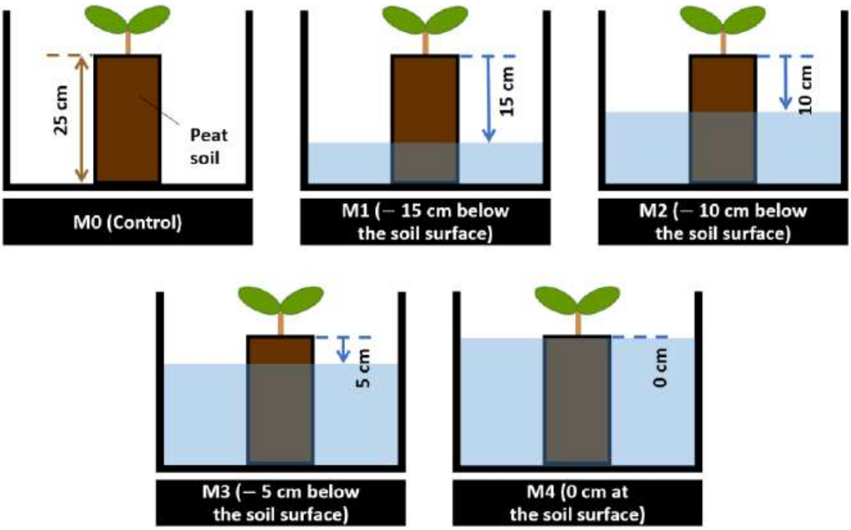

Figure 2 Diagram of experimental design (Maulidya et al., 2024)

Here are the detailed descriptions of the five different groundwater levels. We divided the group into a control group without groundwater level and a group exposed to groundwater levels of various depths. Each groundwater level treatment was applied for 11 days, from 41 to 51 days after sowing.

M0: Not exposed to groundwater, fully drained (control)

M1: –15 cm below the soil surface

M2: –10 cm below the soil surface

M3: –5 cm below the soil surface

M4: 0 cm below the soil surface

03

Research Results

All Tamanu seedlings survived at all groundwater levels, indicating that Tamanu seedlings can survive 100% regardless of groundwater exposure, even at 0 cm below the soil surface. However, there was a clear difference in growth depending on the groundwater level.

To determine the growth of Tamanu seedlings planted in peat soil under the different groundwater level, the plant height (from ground to highest plant body), number of leaves, and root collar diameter (stem diameter at 0 cm above the ground) of the seedlings were measured five times in total; immediately before groundwater level treatment (40 days after sowing), and at 51, 61, 71, and 81 days after sowing.

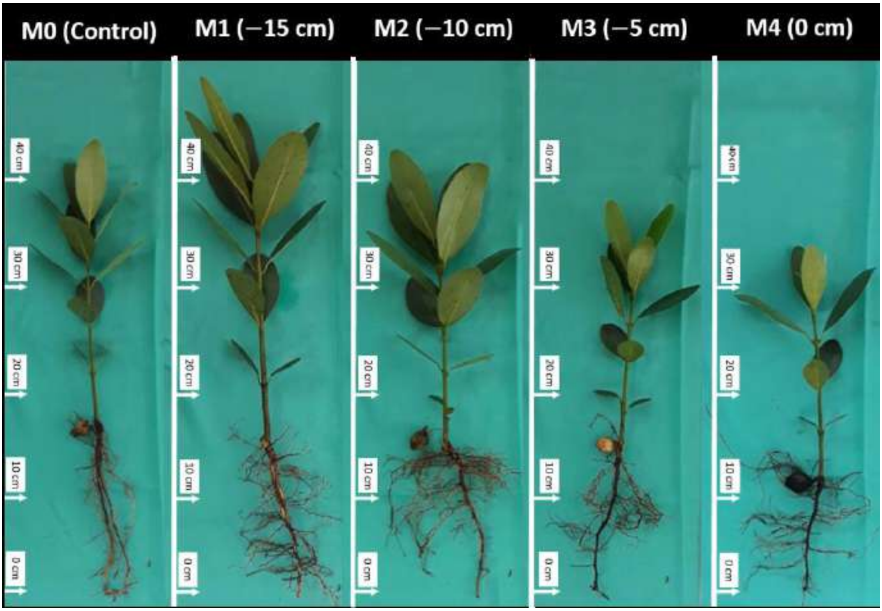

Figure 3 Tamanu seedlings at 81 days after sowing under different groundwater level treatments (Maulidya et al., 2024)

This is what the seedlings treated the different groundwater level looked like 81 days after sowing (Figure 3). Fortunately, they all survived. However, there was a clear difference in growth between the treatment groups. Let's take a closer look at the results of the growth changes.

First, if we examine the results of the plant height, the plant height steadily over time increased in all the groundwater level treatments, but there was difference between treatments. M0 (not exposed to groundwater, control) and M1 (−15 cm below the soil surface) showed no statistically significant difference, while M3 (−5 cm below the soil surface) and M4 (0 cm below the soil surface) had significantly lower heights ($p<0.05$, Figure 4). This indicates that the plant height of Tamanu seedling was not greatly affected when the groundwater level was lower than −15 cm from the surface, similar to the control group without exposure to groundwater. However, when the groundwater level was raised to −5 cm or 0 cm, the plant height decreased.

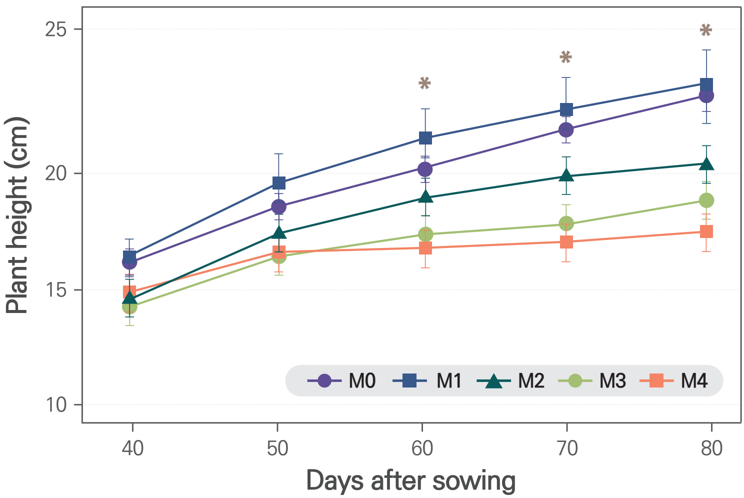

Figure 4 Changes in the plant heights of tamanu seedlings under different groundwater levels 40−81 days after sowing (Maulidya et al., 2024). Dot means the averages of groundwater level and bar means standard errors. Asterisks indicate statistically significant differences at the significance level of 0.05 for each groundwater level treatment group.

The following are the results of the number of leaves. The number of leaves did not increase steadily over time in all groundwater level treatments. At 51 days after sowing, the number of leaves in M3 and M4 decreased, but as time passed, M3 increased higher than the initial count, and M4 recovered to that of 40 days after sowing (Figure 5). At 81 days after sowing, the number of leaves in M0, M1, and M2 were not statistically significantly different, while the number of leaves in M4 was significantly lower ($p<0.05$). This indicates that at 0 cm of a groundwater level from the soil surface (i.e., the peat soil was completely submerged), growth was limited, making it difficult for the number of leaves to increase.

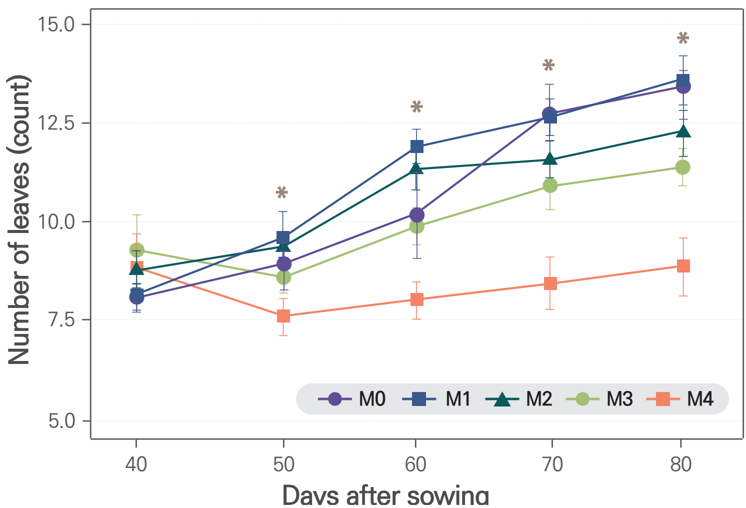

Figure 5 Changes in the number of leaves of tamanu seedlings under different groundwater levels 40–81 days after sowing (Maulidya et al., 2024). Dot means the averages of groundwater level and bar means standard errors. Asterisks indicate statistically significant differences at the significance level of 0.05 for each groundwater level treatment group.

The root collar diameter increased steadily over time across all groundwater treatments (Figure 6). From 61 to 81 days after sowing, M0, M1, M2, and M3 showed no significant difference, while M4 was significantly thinner ($p < 0.05$). It was observed that the root collar diameter struggled to grow at a groundwater level of 0 cm below the soil surface.

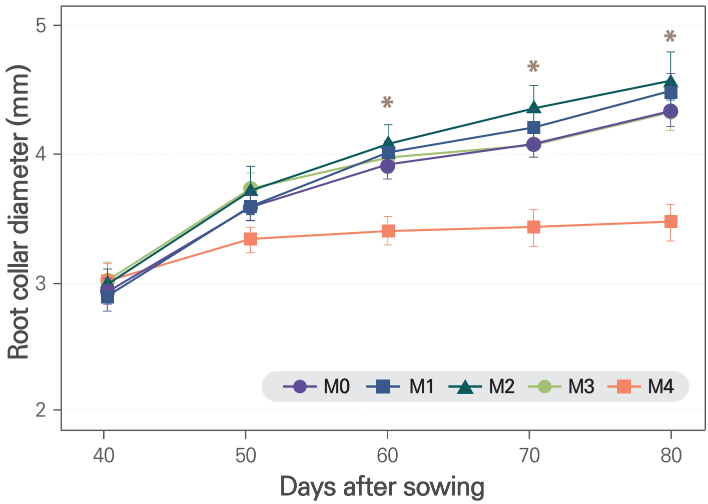

Figure 6 Change in root diameters of tamanu seedlings under different groundwater levels 40–81 days after sowing (Maulidya et al., 2024). Dot means the averages of groundwater level and bar means standard errors. Asterisks indicate statistically significant differences at the significance level of 0.05 for each groundwater level treatment group.

Finally, at 81 day after sowing, the Tamanu seedlings were divided into organs (leaves, stems, and roots), dried for 72 hours, and then measured for biomass. The total biomass did not show a statistically significant difference across groundwater level treatment, but it tended to become higher in M0 and M1, whereas lower in M3 and M4 (Figure 7). There was also no significant difference in the ratio of biomass allocation among the organs (Figure 8). Although the variation in biomass was large for each seedling and no statistically significant difference was found, a tendency for biomass to decrease when the groundwater level increased was identified.

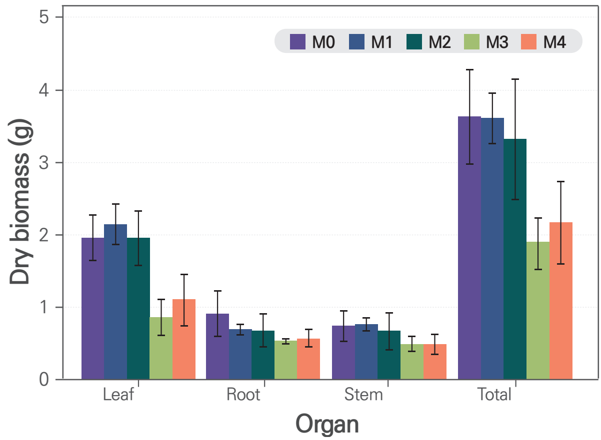

Figure 7 Dry biomass per tamanu seedling at 81 days after sowing under different groundwater level treatments. The bar means standard error (Maulidya et al., 2024).

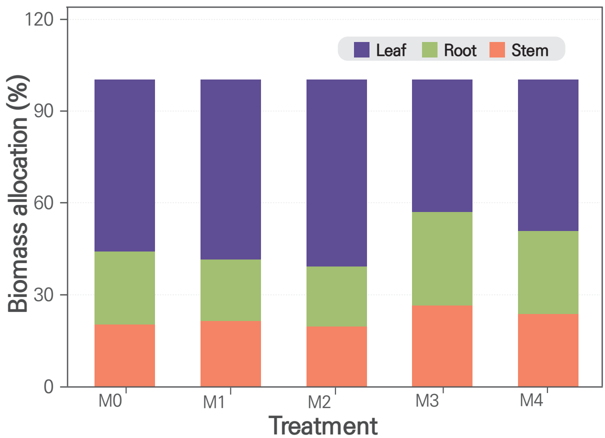

Figure 8 Biomass allocation per tamanu seedling at 81 days after sowing under different groundwater level treatments (Maulidya et al., 2024).

04
Implications

Although all Tamanu seedlings were able to survive in the changes of groundwater level, it was found that their growth was not negatively affected at a groundwater level of -15 cm compared to the control group. However, growth was negatively affected at a groundwater level of 0 cm. The Indonesian government considers tropical peatlands to be in a 'degraded state' when the groundwater level drops more than -40 cm from the surface, since they are irreversibly dried out. Considering this, we confirm that the groundwater level should be maintained between -40 and -15 cm to achieve successful early growth of Tamanu seedlings without damaging the tropical peatlands.

However, this study has limitations. It is difficult to compare whether the responses of Tamanu to groundwater level is sensitive or insensitive compared to other species, since this study deals with only one species. Therefore, the National Institute of Forest Science and the University of Sriwijaya targeted four tree species - Tamanu, Malapari, Jelutong, and Balangaran, which are tropical restoration tree species - to proceed further study with three considerations: (1) seedlings generally are transplanted to the plantation site when the tree height reaches 30 cm, (2) the actual difference in the groundwater level of peatlands is large, ranging from -2 m to 2 m between the dry and rainy seasons, and (3) the maximum flooding period ranges from 3 months to 5 months in Indonesia.

The results of the study will be reported in the upcoming ‘Growth analysis on a peatland restoration species, Tamanu, under different groundwater levels II’. Efforts to respond to climate change with keywords including ‘sustainable use and restoration of tropical peatlands’ will continue with interest and cooperation from international joint researchers.

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